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Prospects of using the UFMC technology in 5G/IMT-2020 networks

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ABSTRACT

Subject of investigation. The article considers the technology of frequency multiplexing with universal filtering UFMC, planned to be introduced in the fifth generation of mobile communication networks, which allows maximizing the rate of decay of the side lobes of the multi frequency signal spectrum that cause out-of-band emissions. Method. As a method of investigation, a computational experiment was chosen. Main results. The parameters of the OFDM and UFMC signals were compared to determine the gain of the UFMC technology in the occupied bandwidth of the signal spectrum, as well as the number of arithmetic operations, required to generate a data symbol compared to the OFDM technology, on the basis of which, conclusions were made about the practical application of UFMC technology in networks mobile communication of the fifth generation. Practical significance. The conducted analysis can help to select the optimal number of sub-channels in groups in order to minimize the amount of computations during the UFMC symbol generation process.

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1. INTRODUCTION

The development of information technology has led to significant changes in all areas of human activity, which in turn leads to a continuous increasing in traffic volumes [1, 2]. Moreover, it is planned that a significant part of this traffic will be the exchange of data of inter-machine interaction. Taking into account all the new tasks that arise in the field of telecommunications, it becomes evident the need to move to new standards in mobile communication networks [3, 4]. And now, the standard of communication networks of the fifth generation is already at the stage of certification. The approval of this standard is planned to be implemented in 2020, after agreement the frequency bands at the World Radio communication Conference and obtaining a positive decision from the International Telecommunication Union. However, even now it is possible to get acquainted with the draft copy of this standard published on the ITU website. According to the data presented in the draft IMT-2020 standard, the speeds of the downstream and upstream digital streams will be 10 and 20 Gbit/s respectively, the downstream and upstream speeds of 100 and 50 Mbit / s are declared for the end user. At the first stage, the organization of fifth-generation networks is planned on the basis of the existing architecture of the fourth-generation networks, which will be gradually supplemented with the latest developments of radio access [5-8]. In existing fourth-generation wireless access networks for data transmission, orthogonal frequency multiplexing OFDM technology is used. Despite the indisputable advantages of this technology, we should note a number of disadvantages, for example: the need for high-

precision synchronization in time and frequency, sensitivity to the Doppler effect, high values of the peak factor. It should also be noted a fairly broad frequency band in which incidental radio emissions of the OFDM signal are observed above a predetermined level. At the same time, increasing the spectral efficiency is quite a challenge. However, there are already several solutions that, along with classical OFDM, are included in the basis of data transmission in the fifth generation communication networks. In this article, one of such technologies will be considered: universal filtered multicarrier (UFMC) [9-12].

2. METHODOLOGY

2.1. Spectral components

The principle of UFMC technology is to maximize the decay rate of the side lobes of the multi frequency signal spectrum at the output of the Fourier transform block with the help of filters with finite impulse response (FIR filters), the weight coefficients of which correspond to the Dolph-Chebyshev window function [13, 9]. An expression describing in general the principle of forming the i-th OFDM symbol on the transmitting side is:

$$\dot{x}^i_{\text{cp}} = \frac{1}{\sqrt{N}} \boldsymbol{A}\boldsymbol{W}^H \dot{\boldsymbol{X}}^i = \boldsymbol{A}\dot{x}^i$$

where $\dot{\boldsymbol{X}}^i$ – i- th complex data frame of duration N, $\boldsymbol{W}^H = (\boldsymbol{W}^T) - N \times N$ – matrix of the inverse discrete Fourier transform (IDFT), arg* – complex conjugate operator, $\dot{x}^i$ – sequence N-point(IDFT), $\dot{\boldsymbol{X}}^i$, $\boldsymbol{A} = \left[\frac{0_{M\times N-M} | \boldsymbol{I}_M}{\boldsymbol{I}_N}\right]$– the block matrix for adding a cyclic prefix, by copying the last M samples $\dot{x}^i$ in the time window between the sequences$\dot{x}^{i-1}$ and$\dot{x}^i$. Then symbol$\dot{x}^i$ enters the digital-to-analog converter, where the OFDM signal is generated [14-17]:

$$x^i(t) = Re\left(\sum_{n=1}^{N} x_n^i \cdot h_{\text{ЦАП}}(t - n\Delta t)\right) \cos(2\pi f_{\text{н}} t),$$

Where $h_{DAC}(t)$ – impulse response DAC.

The symmetry property of the IDFT matrix elements should be noted.$\omega^*_{m,n} = exp\left(2\pi i \frac{m\cdot n}{N}\right)$, where m, n=0…N-1 – row and column number of matrix $\boldsymbol{W}^H$: $Re(\omega^*_{m,n}) = Re(\omega^*_{N-m,n})$, $Re(\omega^*_{m,n}) = Re(\omega^*_{N-m,n})$дл $\forall m = 1 \dots \left(\frac{N}{2}\right) - 1$. The symmetry property is also valid for n. Thus, in order to organize the transmission by N subcarriers, it is necessary to increase the size of the matrix $\boldsymbol{W}^H$ up to 2N, which allows, nevertheless, to form the real signal at the output of the IDFT block due to the Hermitian expansion of the complex data frame:$\dot{\boldsymbol{X}}^i_{N-n} = \left(\dot{\boldsymbol{X}}^i_n\right)^*$, для$\forall n = 1 \dots \left(\frac{N}{2}\right) - 1$. An example of the OFDM symbol for N = 256 and M = N / 8 and its spectrum is shown in Figure 1.

As can be seen from Figure 1, the level of spectral components, that go beyond the band width al located for transmission and which affect the signal transmission in adjacent channels, is quite high.

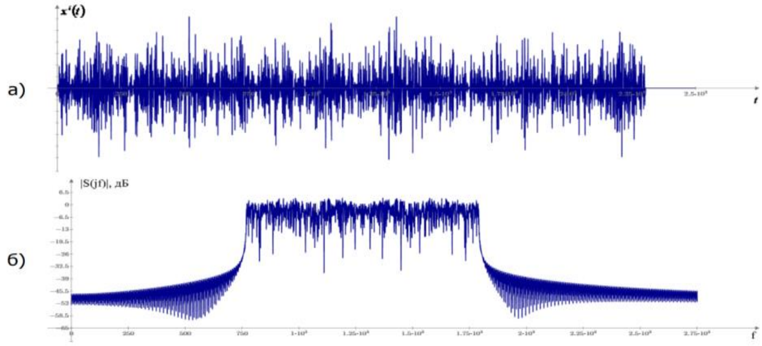

Figure 1. The level of spectral components: a) the OFDM symbol; b) the amplitude spectrum of the OFDM signal

3. RESULTS

In the UFMC technology discussed in this article, the QAM N sub-channel signals are divided into G groups. The complex data frame of each such group at the positions of QAM signals that do not fall within the frequency range of this group contains zero elements. Complex frames of these groups are fed to separate blocks N of a point IDFT, at the output of which FIR filters with impulse characteristics described by the expressions [10, 18] are installed:

$$h_g^i = \left(\sum_{k=0}^{l} \frac{(-1)^l (L-k-2)!ch(arch(10^{\alpha})/N)}{(L-l-k-1)!k!(l-k)!}\right) \cos\left(\frac{2\pi N\cdot g\cdot l}{G\cdot L}\right),$$

where *g*–the number of the subcarrier group 0 ... G-1, L –the length of the filter (odd), selected within the range 0.07 ... 0.1 of the N value, which is commensurable with the length of the cyclic prefix. In Figure 2 the impulse response of FIR filters for 0.7 and 15 groups for G = 16, as well as their spectral characteristics for L = 17, N = 256, insertion damping of the side lobes - 80 dB, are shown.

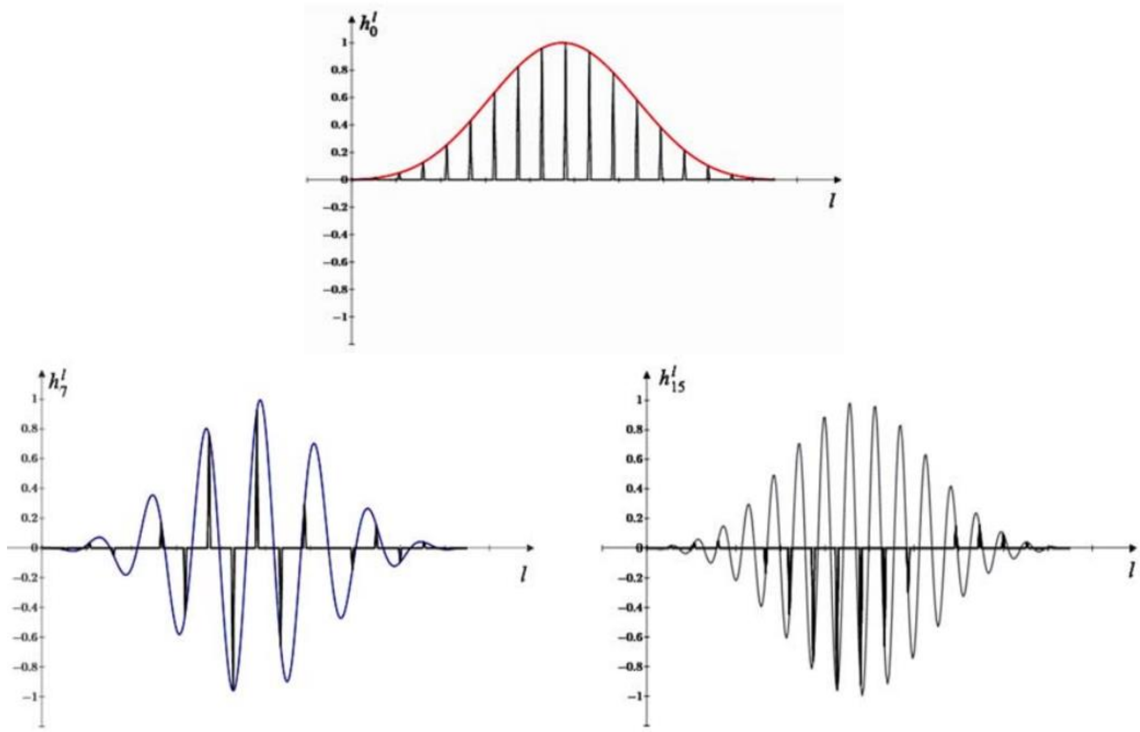

Figure 2. Impulse characteristics of FIR filters for groups g = 0, 7, 15

The formation of the i-th data symbol UFMC as a function of discrete time can be described by the following expression:

$$\dot{x}^{i}_{UFMC} = \frac{1}{\sqrt{2N}}\sum_{g=0}^{G-1} \boldsymbol{H}_g \boldsymbol{W}^H \boldsymbol{D}_g \dot{\boldsymbol{X}}^i = \sum_{g=0}^{G-1} \dot{x}^i_g$$

where $\boldsymbol{D}_g = diag\{d_0, d_1, \dots, d_{2N-1}\}$– matrix of forming a complex data frame of the group, where d_n=1, if n is one of the sub-channel numbers of the given group, and d_n=0,otherwise. $\boldsymbol{H}_g$-$(2N + L - 1) \times 2N$a matrix of an aperiodic convolution of the signal from the output of the IDFT block and the counts of the Dolph-Chebyshev window function, $\dot{x}^i_g$ is the data symbol of the group *g*. The UFMC data symbol is then fed to the DAC and a frequency converter that carries the UFMC signal spectrum to the high-frequency range.

In Figure 3 the spectral characteristics of FIR filters for groups. In Figure 4 the amplitude spectrums of the corresponding groups at the output of the frequency converter are shown. In Figure 5 shows the amplitude spectrums of OFDM and UFMC signals formed from a single complex data frame are shown.

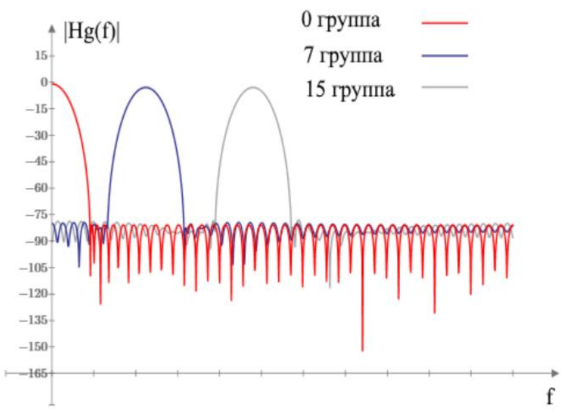

Figure 3. Spectral characteristics of FIR filters for groups g = 0, 7, 15

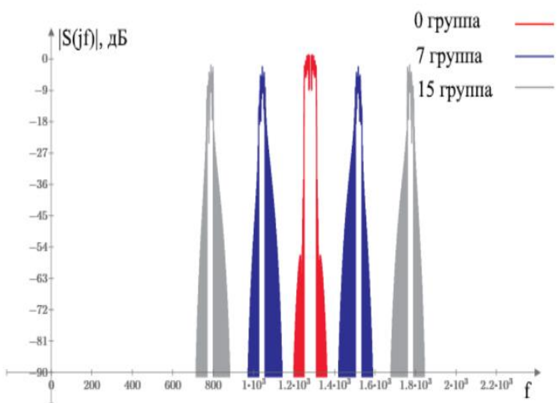

Figure 4. Amplitude spectrums of groups at the output of the frequency converter

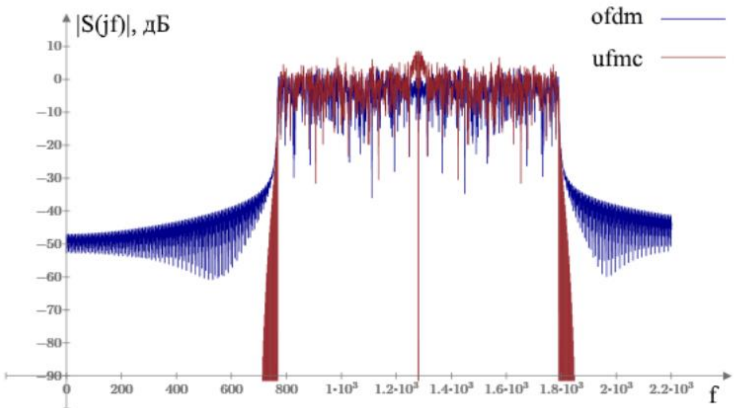

Figure 5. Amplitude spectrums of OFDM and UFMC signals

From Figure 5 it's obvious that UFMC technology effectively eliminates out-of-band emissions. So, if we determine the width of the occupied frequency band of the signal spectraum by the out-of-band radiation level -40 dB, then the UFMC gain over the occupied frequency band is more than 1.2.

3.1. Volumes and Speed of Calculations

At the same time, it is worth to pay attention to the number of calculations required for the formation of OFDM and UFMC symbols. If for the formation of the OFDM symbol in practice it is necessary to perform the IFFT procedure, which takes into account the Hermitian symmetry $N\log_2(2N)$ operations of complex multiplication and $2N\log_2(2N)$ complex addition, then for the formation of the UFMC symbol, the IFFT procedures are required in G times larger and, therefore, in G times more calculations. The subsequent convolution of the real output sequence of the IFFT block with the impulse response of the FIR filter of the group of length L requires $G(2N+L-1)L$ multiplications and $G(2N+L-1)(L-1)$ additions [19-24]. As well as, it will be necessary to perform $G(2N+L-1)$ operations of adding symbol counts of these groups.

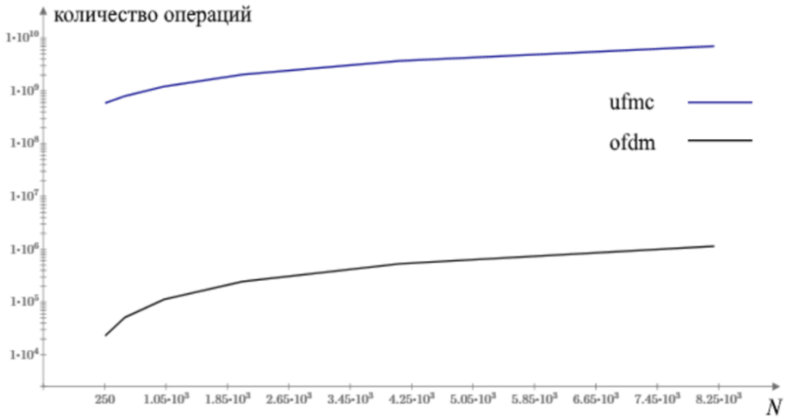

Figure 6. Dependence of the number of arithmetic operations required for the formation of OFDM and UFMC symbols, on the number of sub-channels N

In Figure 6, a graph that shows the dependence of the number of arithmetic operations required for the formation of OFDM and UFMC symbols on the number of sub-channels N is presented. Calculations of the UFMC symbol were made for the case of 16 sub-channels in the group and the filter length L = 0.07 (2N). As can be seen from the graphs, the number of arithmetic operations required to generate a UFMC symbol is at least four orders greater than the number of operations required to generate an OFDM symbol.

4. CONCLUSION

In the course of this work, the UFMC technology for data transmission in the standards of 5G / IMT-2020 networks was considered. And also it was compared with the OFDM technology, used in the networks of the fourth generation. It can be concluded that, despite the advantages in terms of economy of the bandwidth used for transmission, UFMC technology requires incommensurably large amounts of computation, which can significantly complicate the practical implementation of this technology, especially taking into account the transmission speeds that are planned to be provided to the final users.

REFERENCES

[1] Kucheryavy A.E. "Internet of Things". *Electrosvyaz*. 2013. No. 1.pp. 21-24.
[2] Volkov A., Khakimov A., Muthanna A., Kirichek R., Vladyko A., Koucheryavy A. "Interaction of the IoT traffic generated by a smart city segment with SDN core network". *Lecture Notes in Computer Science*. 2017. Vol. 10372. pp. 115-126.

[3] Mukhisi S., Kirichek R. V. “Analysis of the application possibility of SDN, NFV in mobile 5G networks”. *Youth Scientific School on Applied Theory of Probabilities and Telecommunication Technologies (APTCT)*. 2017. pp. 166-174.
[4] Kucheryavy A.E., Prokopiev A.V., Kucheryavyy E.A. “Self-organizing networks”. St. Petersburg: Lubavitch, 2011. 312 p.
[5] Ragimova S. Thirst for speed. URL: https://www.kommersant.ru/ doc / 3006299.
[6] Li, S., Da Xu, L., & Zhao, S. “5G Internet of Things: A survey”. *Journal of Industrial Information Integration,* 2018, 10, 1-9.
[7] Mumtaz, S., Huq, K. M. S., Rodriguez, J., Ghosh, S., Ugwuanyi, E. E., Iqbal, M., & Lykourgiotis, “A. Self-organization towards reduced cost and energy per bit for future emerging radio technologies-sonnet”. In 2017 *IEEE Globecom Workshops (GC Wkshps),* (2017, December),(pp. 1-6. *IEEE*.
[8] Weng, C. W., Sahoo, B. P., Wei, H. Y., & Yu, C. H. “Directional reference signal design for 5G millimeter wave cellular systems”. *IEEE Transactions on Vehicular Technology*, 2018, 67(11), 10740-10751.
[9] Vakilian V., Wild T., Schaich F., Brink S., Frigon J.-F. “Universal-Filtered Multi-Carrier Technique for Wireless Systems Beyond LTE, *IEEE Globecom Workshops (GC Wkshps).* 2013. pp. 223-228.
[10] Dvorkovich A.V., Dvorkovich V.P. “Window functions for harmonic analysis of signals”. M.: Technosphera, 2014. 112 p.
[11] Eficher E., Jervis. B. “Digital signal processing”. *Practical approach*. 2nd ed. M.: Williams, 2004. 992 p.
[12] Saud, S., Bangash, A. K., & Ali, S. R. (2016). “The Nexus of Peer Group Environment with Emotional Intelligence: A Statistical Analysis”. *Global Social Sciences Review*, I(II), 45-58. doi:10.31703/gssr.2016(I-II).04.
[13] Saeed, I. U., Jehangir, M., & Tariq, M. (2018). “The Impact of Education, Health, Experience and Government Loans on Farmers’ Productivity in District Nowshera”. *Global Social Sciences Review*, III(I), 83-100. doi:10.31703/gssr.2018(III-I).06
[14] Tawfikur Rahman, S. M. A. Motakabber, Muhammad I. Ibrahimy, A. H. M. Zahirul Alam, “Design and implementation of a series switching SPSI for PV cell to use in carrier based grid synchronous system”, vol 8, no. 2, 2019, 349-366.
[15] M. Norazizi Sham Mohd Sayuti, Farida Hazwani Mohd Ridzuan, Zul Hilmi Abdullah, “Task mapping and routing optimization for hard real-time Networks-on-Chip”, vol 8, no. 2, 2019, 349-366.
[16] Aparna Prayag, Sanjay Bodkhe, “Novel Symmetric and Asymmetric Multilevel Inverter Topology for Permanent Magnet Synchronous Motor”, *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. , no. 3, 2017, 1002-1010.
[17] Mehdi Safdari, Alireza, Arab bafrani, Afsaneh Bagheri Ghomi, “Realization of economic justice through teleworking”. *UCT Journal of Management and Accounting Studies*, 2013, 1, 4, pp.11-13.
[18] Andi Pawawoi, Wahyu Prabowo, “Effect of PWM Duty Cycle and Frequency of Power Supply to the LED Bulb Efficacy”, *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. no. 3, 2017, 1011-1015.
[19] Marzbanrad, J., Soleimani, G., Mahmoodi-k, M., & Rabiee, A. H. (2015). “Development of fuzzy anti-roll bar controller for improving vehicle stability”. *Journal of Vibroengineering*, 17(7), 3856-3864.
[20] Montazeri-Gh, M., & Mahmoodi-k, M. (2015). “Development a new power management strategy for power split hybrid electric vehicles”. *Transportation Research Part D: Transport and Environment*, 37, 79-96.
[21] Montazeri-Gh, M., & Mahmoodi-K, M. (2016). “Optimized predictive energy management of plug-in hybrid electric vehicle based on traffic condition”. *Journal of cleaner production*, 139, 935-948.
[22] Li, S., Da Xu, L., & Zhao, S. (2018). “5G Internet of Things: A survey”. *Journal of Industrial Information Integration*, 10, 1-9.
[23] Ali Hatamizadeh, Yuanping Song, Jonathan B. Hopkins, “*Geometry Optimization Of Flexure System Topologies Using The Boundary Learning Optimization Tool (Blot)”*, Proceedings of the ASME 2017 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, IDETC/CIE 2017, August 6-9, 2017, Cleveland, Ohio, USA.
[24] Ahmad, S., Bakht, M., & Hussan, S. (2016). “Pakistan’s Internal Security Dilemma: Strategic Dimension”. *Global Social Sciences Review*, I(II), 1-17. doi:10.31703/gssr.2016(I-II).01